Two Way Generic Airport Simulation Application

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***Abstract*—This project aims to illustrate, build, simulate and analyze a generic conceptualized airport. The queues in this simulation are based on *Kendall's notation in the queueing theory*. The approaches taken to complete this work were as follows: Theoretical and Hypothetical to conceptualize the model, Analytical to analyse the system made from the model, "Comparative to make sure that the data is as close to reality as possible". The results of this paper are: a fully functioning airport simulation that is also configurable along with a friendly graphical user interface to lessen the complexity of the code and make the outputs more clear. Hence, it is clear that *Kendall's* work was able to make the modeling and simulation of queues a much simpler task than it was before then.**

***Index Terms*—Generic airport, Theoretical , Conceptualize, Modeling, Queueing, Kendall.**

I. Introduction

The ability to model and simulate our surroundings is an ability that Humans have aqcuired through thousands of years of experience, evolution, wisdom and countless contributions by countless great scientists. Specifically, the British scientist David George Kendall who proposed the idea of giving queues descriptions using three descriptive factors such as "M/M/1" or more generically speaking "Arrival/Service/number of servers" in 1953 [1].

A. Problem statement

Queues are a common problem in every airport around the world. Around 5% of people miss their plane due to various reasons, however the main reason is waiting in queues whether it's an airline counter or at a security queue. Queuing times are considered a major problem and in order to solve this problem various options can be explored, however they can be time depleting and expensive. Consequently, simulations were used. They are inexpensive, reduce danger and can be sped up so behavior can be studied easily over a long period of time or can be slowed down to study behavior more closely.

B. Target Beneficiaries of the Project

To accurately explore the impact of our project, we need to consider the beneficiaries of the project. There are two different categories of beneficiaries and they are described as follows:

- **Direct beneficiaries:** are the people who are directly involved with the airport. First, we have the passengers that use the aiport for their travels, then we have the airline companies and their workers such as the TSA agents, pilots and flight attendants and finally we have the maintenance crew who are responsible for the planes and runway maintenance.
- **Indirect beneficiaries:** are the people who are implicitly involved with the airport such as: taxi and limo services, public transportations, the governments and the community as a whole since the reduction of queue times and delays speeds up the process which helps people get to their destinations faster and companies can make more money

C. Anticipated Time plan

The anticipated time plan of all phases of the project along with the detailed tasks is shown in fig. 1 with a Gantt chart showing the timing details of each task.

II. System Design

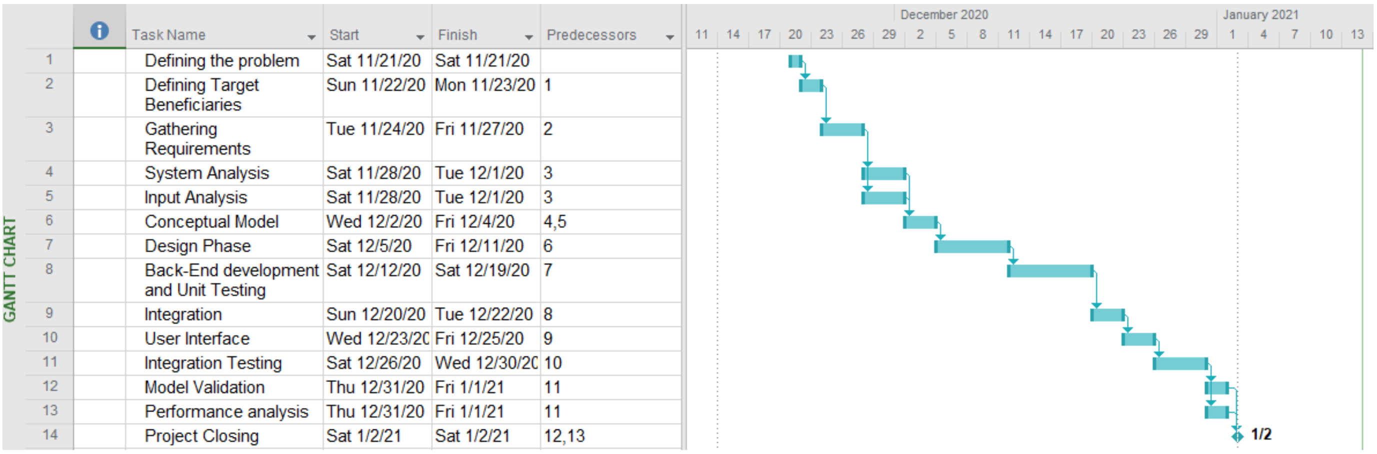
A. Conceptual Simulation Model

First off, we have assumed that each airline company operates a total of six planes daily, starting from time zero which is midnight a plane would take off every 4 hours $(24Hr * \frac{1}{4}\frac{Plane}{Hr}) = 6$ planes Supposedly, for the passengers to board these planes they will have to first pass by a counter for a specific company, and each passenger will be allocated to a different company counter based on their status. Further explanation:

- **VIP counter:** The passenger will be queued to the server with average service time of 2 or 3 min.
- **Economy without luggage:** The passenger will be queued to the server with average service time of 2 min.
- **Economy:** The passenger will be queued to the server with average service time of 3 min.

After the counter queue, each passenger would then have to be queued in a security counter regardless of their status, and may be delayed before reaching the security counter by 5 to 15 minutes, upon reaching the security counter they will be checked within 2 minutes on average. Lastly, the passengers who have been checked and approved by security will move on to their designated gate (Gate 1, Gate 2, Gate 3, Gate 4) which is also designated randomly in the simulation, and the delay to reach the designated gate from the secuity counter is as follows:

- Delay from Security to **G1** is a uniformly distributed random variable **from 00 to 05 minutes**.
- Delay from Security to **G2** is a uniformly distributed random variable **from 05 to 10 minutes**.



	Task Name	Start	Finish	Predecessors
1	Defining the problem	Sat 11/21/20	Sat 11/21/20	
2	Defining Target Beneficiaries	Sun 11/22/20	Mon 11/23/20	1
3	Gathering Requirements	Tue 11/24/20	Fri 11/27/20	2
4	System Analysis	Sat 11/28/20	Tue 12/1/20	3
5	Input Analysis	Sat 11/28/20	Tue 12/1/20	3
6	Conceptual Model	Wed 12/2/20	Fri 12/4/20	4,5
7	Design Phase	Sat 12/5/20	Fri 12/11/20	6
8	Back-End development and Unit Testing	Sat 12/12/20	Sat 12/19/20	7
9	Integration	Sun 12/20/20	Tue 12/22/20	8
10	User Interface	Wed 12/23/2C	Fri 12/25/20	9
11	Integration Testing	Sat 12/26/20	Wed 12/30/2C	10
12	Model Validation	Thu 12/31/20	Fri 1/1/21	11
13	Performance analysis	Thu 12/31/20	Fri 1/1/21	11
14	Project Closing	Sat 1/2/21	Sat 1/2/21	12,13

Fig. 1: Anticipated time plan

- Delay from Security to **G3** is a uniformly distributed random variable **from 10 to 15 minutes**.
- Delay from Security to **G4** is a uniformly distributed random variable **from 15 to 20 minutes**.

Furthermore, we have assumed that each plane is capable of holding one hundred passengers at a time, and within these 100 passengers there will always twenty VIP seats and the rest is economy. In the event that a passenger arrives to the airport and tries to get their boarding pass after three and a half hours have passed from the four hours alloted for the them to arrive they will be rejected, and in the case that they reach the gate after four hours have passed then they will be denied entry and will not board the plane, since it will have already departed and all of these assumptions are shown in fig. 3.

All assumptions made in the departure process are applied in the arrival process with the difference in all arriving airlines will be using the same gate instead of separate gates as mentioned in the departure process. The passengers supposedly to exit these planes will have to first pass by the visa clearance counters, however they may be delayed before reaching the visa clearance clearance counters by 3-8 minutes. After each passenger reach the visa clearance, they will be allocated to a different counter based on their nationality, as a default there will be 4 counters for locals and 2 counters for foreigners. Passengers will be queued to the server with average service time of 1 minute for both local and foreigner passengers.

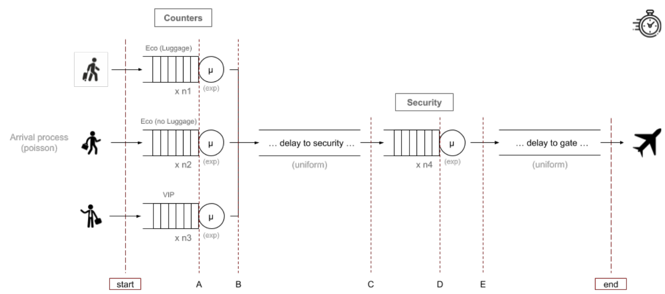


Fig. 3: The Conceptual model for the depature process

After each passenger has been admitted and has passed through the visa clearance counters, they will be queued for the luggage belt assuming they have luggage and may be delayed before reaching the security counter by 5-10 minutes, upon reaching the luggage belt they will wait for their luggage to arrive within 5-30 minutes. After each passenger has received their luggage (given they have any), they will be queued for 4 security counters no matter what their status is and may be delayed before reaching the security counter by 3-8 minutes, upon reaching the security counter they will be checked within 2 minutes in average. Upon being inspected and approved, all passengers will be able to enter the country within 5-10 minutes as illustrated in fig. 2.

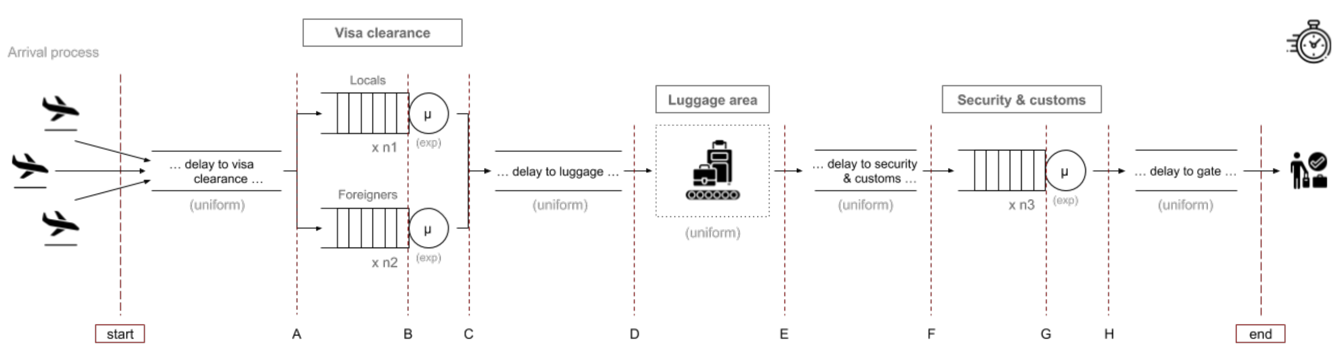


Fig. 2: The Conceptual model for the arrival process

B. *Input Analysis*

1) Exponential and Poisson Probability Distributions: The exponential distribution with parameter λ is given by $\lambda * e^{-(\lambda * t)}$ for $t \geq 0$. If T is a random variable that represents interarrival times with the exponential distribution, then $P(T \leq t) = 1 - e^{(-\lambda * t)}$ and $P(T < t) = e^{(-\lambda * t)}$. This distribution lends itself well to modeling customer interarrival times or service times for a number of reasons. The first is the fact that the exponential function is a strictly decreasing function of t. This means that after an arrival has occurred, the amount of waiting time until the next arrival is more likely to be small than large. Another important property of the exponential distribution is what is known as the no-memory property. The no-memory property suggests that the time until the next arrival will never depend on how much time has already passed. This makes intuitive sense for a model where we're measuring customer arrivals because the customers' actions are clearly independent of one another. It's also useful to note the exponential distribution's relation to the Poisson distribution. The Poisson distribution is used to determine the probability of a certain number of arrivals occurring in a given time period. The Poisson distribution with parameter λ is given by $\frac{(\lambda * t)^n * e^{(-\lambda * t)}}{n!}$ where n is the number of arrivals. We find that if we set n = 0, the Poisson distribution gives us $e^{-(\lambda * t)}$ which is equal to $P(T > t)$ from the exponential distribution. The relation here also makes sense. After all, we should be able to relate the probability that zero arrivals will occur in a given period of time with the probability that an interarrival time will be of a certain length. The interarrival time here, of course, is the time between customer arrivals, and thus is a period of time with zero arrivals. With these distributions in mind, we can begin defining the input processes of our queuing system, from which we can start developing the model further.

2) input process: The finite or infinite random arrival on queues is defined as stochastic process also known as Markov (or memoryless) process described by Poisson distribution. Service times are independently and identically distributed or exponentially distributed random variables. To begin modeling the input process, we define t_i as the time when the i^{th} customer arrives. For all $i \geq 1$, we define $T_i = t_{i+1} - t_i$ to be the i^{th} interarrival time. We also assume that all T_i's are independent, continuous random variables, which we represent by the random variable A with probability density a(t). Typically, A is chosen to have an exponential probability distribution with parameter λ defined as the arrival rate, that is to say, $a(t) = \lambda * e^{-(\lambda * t)}$. It is easy to show that if A has an exponential distribution, then for all nonnegative values of t and h, $P(A > t + h | A \geq t) = P(A > h)$This is an important result because it reflects the no-memory property of the exponential distribution, which is an important property to take note of if we're modeling interarrival times.

C. *System Analysis*

The two-way airport system in this simulation is presented as a:

- Dynamic system due to its ability to have its values manipulated.
- Discrete state – continuous time system.
- Event-oriented, each variable is subject to change depending on the state.
- Stochastic system.

This simulation's objective is to create a reasonable time for passengers to reach their plane without delay and improve the waiting time as well as the service time for each queue. Furthermore, the airport has some common elements such as the airlines counters, airplanes, security staff and passengers each one of them represent a fundamental part to the airport. Moreover, the whole simulation was created in order to simulate the queueing process, the number of queues can be modified to suit most airports whether it's a large international airport or a local regular one. Additionally, the simulation uses different parameters for both the Departure and Arrival processes. The Departure process has 10 parameters such as the number of VIPs, the probability of a passenger having no luggage, the average inter-arrival time, the average counter service time for passengers with both luggage and no luggage, the average service time at the security check and finally the upper and lower bound time to arrive at the gate. After adjusting the configuration, parameters are passed to the system, so that we can measure the system performance metrics such as the average waiting time for the passenger (W_s), as well as the average waiting time in the queue (W_q) and the percentage at which the queues remain idle. All the previously mentioned performance metrics are calculated for economy class passengers with and without luggage, VIP passengers and passengers at the security queue. The Arrival process has almost the same parameters of the arrival process such as the probability of a foreigner passenger arriving, the probability of having no luggage, the service time at the visa clearance counter, the upper and lower bound time to arrive at the visa clearance counter, the upper and lower bound time delay to arrive at the luggage belt for pickups, as well as the security and customs arrival and service time, the probability of rejecting the passenger's visa and finally the upper and lower bound time to arrive at the airport's exit gate. Once again, after passing the configuration paramaters we are able deduce the system performance metrics of the arrival process such as the average waiting time for the passenger (W_s), as well as the average waiting time in the queue (W_q). All of metrics previously disccussed are calculated for both foreign and local passengers at the visa clearance counters and at the security and customs.

III. Model validation

Simulation models are mere imitations of the real-world systems and are rarely 100% accurate, due to that we validate our outputs to ensure that they are acceptable with respect to the real-world processes. Therefore, our values were generalized and based on feedback from real-world travelers, our simulation's average outputs were compared with average outputs from real functioning planes and airports. However, all inputted values can be modified to simulate different airports as well as different times, showing the difference between when the airport had few companies operating and when the airport had all airline companies operational. Thus, we were able to test the model's limitations and adjust the expectations accordingly. The values were constantly validated throughout the simulation to ensure that all alterations were appropriate and calibrate the values which were out of scope.

IV. Performance analysis

A stochastic simulation model will not give the same result when run repetitively with independent random seeds. Hence, one run is not sufficient to obtain confident simulation results from one sample. In the following section, statistical Analysis of simulation result using multiple runs is going to be used to estimate the metrics of interest with 95% confidence level.

The analysis is going to be performed using the default configurations and parameter, having the following numbers of "queue and server" pairs in the departure and arrival processes:

- 1 eco – luggage counter queue and server
- 1 eco – no luggage counter queue and server
- 1 VIP counter queue and server
- 1 security queue and server
- 4 local visa clearance queues and servers
- 2 foreigner visa clearance queues and servers
- 4 security and customs queues and servers

The simulation was configured to run 365 days (a year) for two companies with 6 planes per company and a 100 passengers in each plane, having a total of 1200 passengers per day. The following performance metrics are goings to be estimated for each of the previously mentioned queuing systems: $W_q, W_s, L_q, Idleness\%$
Using 95% confidence level, margin of error $= 1.96\frac{s}{\sqrt{n}}$

Departure process

Eco – luggage counter:

- $W_q = 12.6961 \pm 0.27032$ min
- $W_s = 3.0017 \pm 0.011526$ min
- $L_q = 3.4046 \pm 0.0769$ passenger
- $Idleness\% = (21.6647 \pm 0.34267)\%$

Eco – no luggage queue counter

- $W_q = 0.33779 \pm 0.012543$ min
- $W_s = 1.9994 \pm 0.014687$ min
- $L_q = 0.023786 \pm 0.00096869$ passenger
- $Idleness\% = (86.8786 \pm 0.13203)\%$

VIP counter

- $W_q = 0.84217 \pm 0.02504$ min
- $W_s = 2.8154 \pm 0.020518$ min
- $L_q = 0.062073 \pm 0.0018797$ passenger
- $Idleness\% = (79.4618 \pm 0.16336)\%$

Security

- $W_q = 8.69 \pm 0.18177$ min
- $W_s = 1.9983 \pm 0.0061439$ min
- $L_q = 3.5248 \pm 0.075751$ passenger
- $Idleness\% = (20.0492 \pm 0.28596)\%$

Arrival process

Local visa clearance 1

- $W_q = 14.2087 \pm 0.11793$ min
- $W_s = 1.0052 \pm 0.0064045$ min
- $L_q = 2.4138 \pm 0.019755$ passenger
- $Idleness\% = (82.9535 \pm 0.099282)\%$

Local visa clearance 2

- $W_q = 14.2655 \pm 0.1187$ min
- $W_s = 1.0114 \pm 0.006647$ min
- $L_q = 2.3868 \pm 0.019749$ passenger
- $Idleness\% = (83.1134 \pm 0.10211)\%$

Local visa clearance 3

- $W_q = 14.2035 \pm 0.11943$ min
- $W_s = 1.0124 \pm 0.0067582$ min
- $L_q = 2.3416 \pm 0.019255$ passenger
- $Idleness\% = (83.3425 \pm 0.1006)\%$

Local visa clearance 4

- $W_q = 14.137 \pm 0.11924$ min
- $W_s = 1.0079 \pm 0.006783$ min
- $L_q = 2.3011 \pm 0.019073$ passenger
- $Idleness\% = (83.6201 \pm 0.099526)\%$

Foreigner visa clearance 1

- $W_q = 5.0534 \pm 0.092519$ min
- $W_s = 1.0099 \pm 0.0093727$ min
- $L_q = 0.44377 \pm 0.0095103$ passenger
- $Idleness\% = (91.4239 \pm 0.081923)\%$

Foreigner visa clearance 2

- $W_q = 4.9352 \pm 0.096498$ min
- $W_s = 1.0127 \pm 0.0094167$ min
- $L_q = 0.40828 \pm 0.0096339$ passenger
- $Idleness\% = (91.9318 \pm 0.08446)\%$

Security & customs 1

- $W_q = 21.3913 \pm 0.19704$ min
- $W_s = 2.0246 \pm 0.011499$ min
- $L_q = 4.547 \pm 0.039066$ passenger
- $Idleness\% = (56.9689 \pm 0.18601)\%$

Security & customs 2

- $W_q = 21.5559 \pm 0.2159$ min
- $W_s = 2.0242 \pm 0.011924$ min
- $L_q = 4.4445 \pm 0.039726$ passenger
- $Idleness\% = (58.228 \pm 0.17517)\%$

Security & customs 3

- $W_q = 21.5143 \pm 0.20912$ min
- $W_s = 2.0174 \pm 0.012156$ min
- $L_q = 4.3346 \pm 0.037823$ passenger
- $Idleness\% = (59.3585 \pm 0.1807)\%$

Security & customs 4

- $W_q = 21.4627 \pm 0.21232$ min
- $W_s = 2.0101 \pm 0.012459$ min
- $L_q = 4.2332 \pm 0.037981$ passenger
- $Idleness\% = (60.3317 \pm 0.18932)\%$

V. PROPOSED IMPROVEMENTS

The following two figures show the default configurations for the both simulations and we will discussing them respectively in the order of departure then arrival.

DEP CONFIGS

vip_count	20	propability_nLuggage	0.2
avg_interArrivalTime	2.1	avg_counterServTime_Luggage	3
avg_counterServTime_nLuggage	2	LB_securityDelay	5
UB_securityDelay	15	avg_securityServTime	2
LB_delayToFirstGate	0	UB_delayToFirstGate	5
nQueues_eno_luggage	1	nQueues_eno_nLuggage	1
nQueues_VIP	1	nQueues_security	1

Fig. 4: Default configuration of the departure process

ARR CONFIGS

propability_foreigner	0.2	propability_nLuggage	0.2
LB_interArrivalTime	0.08333	UB_interarrivalTime	0.08333
LB_delayToVisaClr	3	UB_delayToVisaClr	8
avg_visaClrServTime	1	LB_delayToLuggageArea	5
UB_delayToLuggageArea	10	LB_luggageDelay	5
UB_luggageDelay	30	LB_delayToSecCus	3
UB_delayToSecCus	8	avg_securityCusServTime	2
LB_delayToGate	5	UB_delayToGate	10
propability_rejection	0.01	nQueues_foreigner	4
nQueues_local	2	nQueues_secCus	4

Fig. 5: Default configuration of the arrival process

Furthermore, due to the stochastic and configurable nature of our simulation, we can not propose improvements unless we tie them down with certain constraints. Thus, we assume that the proposed improvements will be made on the base model that we have created and as such here are the results that we have obtained by using the default configuration and running it for 1 year.

Egyptair

	eco_luggage 1	eco_nLuggage 1	VIP 1	security 1
Wq	12.9211	0.3365	0.8059	8.5965
Ws	3.0105	1.9940	2.7938	2.0029
Lq	3.4769	0.0237	0.0593	3.4843
idleness%	0.2135	0.8693	0.7969	0.1991

	otherStats
nExcluded_counter	3.9443
nExcluded_gate	6.6247

Fig. 6: Departure simulation results of Egyptair on default config

Japan Airlines

	eco_luggage 1	eco_nLuggage 1	VIP 1	security 1
Wq	12.9602	0.3343	0.7816	8.4806
Ws	3.0055	1.9885	2.7928	1.9926
Lq	3.4827	0.0233	0.0577	3.4358
idleness%	0.2161	0.8700	0.7967	0.2041

	otherStats
nExcluded_counter	4.0744
nExcluded_gate	6.5365

Fig. 7: Departure simulation results of Japan Airlines on default config

Looking at fig. 6 and fig. 7 we can clearly see that the waiting times at the Eco_luggage$_{default}$ = 12.9406 counter and the security$_{default}$ = 8.5385 counters are massive and they cause alot of waiting times in the simulation and the nExcluded_counter$_{default}$ = 4.0108, nExcluded_gate$_{default}$ = 6.5801. Which is why we have proposed the following improvements for the departure part simulation:

- the addition of 1 more security queue
- the addition of 1 more economy luggage queue

and the following figures will show the results of the improvements:

Egyptair

	eco_luggage 1	eco_luggage 2	eco_nLuggage 1	VIP 1	security 1	security 2
Wq	1.1386	0.8341	0.3270	0.8122	0.7593	0.5767
Ws	3.0359	3.0314	1.9930	2.8080	2.0038	2.0052
Lq	0.1822	0.0868	0.0227	0.0599	0.1864	0.0898
idleness%	0.5120	0.6999	0.8702	0.7952	0.5055	0.6971

	otherStats
nExcluded_counter	3.9635
nExcluded_gate	0.4123

Fig. 8: Improved departure simulation results of Egyptair

Japan Airlines

	eco_luggage 1	eco_luggage 2	eco_nLuggage 1	VIP 1	security 1	security 2
Wq	1.1622	0.8501	0.3461	0.8359	0.7790	0.5867
Ws	3.0437	3.0546	2.0055	2.8038	2.0152	2.0264
Lq	0.1860	0.0885	0.0242	0.0619	0.1913	0.0914
idleness%	0.5119	0.6973	0.8695	0.7956	0.5037	0.6938

	otherStats
nExcluded_counter	4.0740
nExcluded_gate	0.4438

Fig. 9: Improved departure simulation results of Japan Airlines

it can be seen that after the improvements we can notice that Eco_luggage$_{improved}$ = 0.98635 and security$_{improved}$ = 1.35085, nExcluded_counter$_{improved}$ = 4.0187 and nExcluded_gate$_{improved}$ = 0.42805 specifically the counters have had their times drastically cut by

$$\frac{|Eco\_luggage_{default} - Eco\_luggage_{improved}|}{Eco\_luggage_{default}} \tag{1}$$

eq. 1 yeilds an improvment of 92.38%

$$\frac{|security_{default} - security_{improved}|}{security_{default}} \tag{2}$$

eq. 2 yeilds an improvment of 84.17%

$$\frac{|nExcluded\_gate_{default} - nExcluded\_gate_{improved}|}{nExcluded\_gate_{default}} \tag{3}$$

and eq. 3 yields an imrpovment of 93.49% which means that a huge amount of people no longer get excluded at the gates due to queuing issues. However, the number of people excluded at the counters did not see an improvement worth mentioning. Secondly, in order to improve the arrival simulation we have proposed the following:

- the addition of 2 more security customs counters.

	ɐign 1	visaClr_foreign 2	visaClr_foreign 3	visaClr_foreign 4	visaClr_local 1	visaClr_local 2	secCus 1	secCus 2	secCus 3	secCus 4
Wq	14.1483	14.1200	14.1903	14.0205	5.0436	4.9020	21.3123	21.3707	21.6046	21.583
Ws	1.0001	1.0015	1.0075	1.0016	1.0141	1.0104	2.0179	2.0091	2.0205	2.024
Lq	2.4057	2.3650	2.3329	2.2816	0.4424	0.4055	4.5289	4.4418	4.3442	4.238
idleness%	0.8302	0.8326	0.8347	0.8373	0.9139	0.9195	0.5711	0.5824	0.5937	0.602

nRejected = 0.97671

Fig. 10: Arrival simulation results on default config

	visaClr_foreign 1	visaClr_foreign 2	visaClr_foreign 3	visaClr_foreign 4	visaClr_local 1	visaClr_local 2	secCus 1	secCus 2	secCus 3	secCus 4	secCus 5	secCus 6
Wq	14.1965	14.2662	14.1374	14.1512	5.0714	4.9056	7.6539	7.6478	7.6638	7.6401	7.5958	7.6206
Ws	1.0038	1.0100	1.0051	1.0097	1.0122	1.0110	2.0566	2.0435	2.0411	2.0386	2.0347	2.0513
Lq	2.4124	2.3845	2.3339	2.3009	0.4436	0.4060	1.1340	1.0889	1.0463	1.0049	0.9637	0.9267
idleness%	0.8296	0.8315	0.8343	0.8362	0.9143	0.9195	0.6940	0.7083	0.7205	0.7315	0.7421	0.7511

nRejected = 1.0107

Fig. 11: Improved Arrival simulation results

upon inspecting fig. 10 and 11, we can see that the values for secCus$_{default}$ = 21.468 and secCus$_{improved}$ = 7.637 respectively.

$$\frac{|secCus_{default} - secCus_{improved}|}{secCus_{default}} \tag{4}$$

Hence, we can see that adding two more security and customs queues has cut the queue times by the result of eq. 4 which is 63.92%.

VI. Conclusion

As this paper has demonstrated, a two-way airport was simulated to create a model of departing as well as arriving passengers. The airport was divided into two sections, starting with the departing passengers' section, multiple companies were created therefore creating planes with passengers, this simulation allowed us to perceive the average waiting times as well as the average service times at company counters, security checks as well as the boarding procedure for all types of passengers (Passengers with luggage, Passengers with no luggage, VIP passengers). However, not all passengers arrive at their designated time therefore with this simulation multiple passengers were rejected at either the boarding gate or the company's counters, this is dependent on the time they have arrived with the amount of time left for the plane to depart. On the other hand, the arriving passengers' section is quite similar to the departing passengers' section. Starting with multiple companies being created, initializing planes with a specific number of passengers arriving at the simulated airport. First off, passengers arriving at an airport have been classified into locals or foreigners then once again divided into passengers who have luggage and passengers who don't have any luggage. Therefore, we were able to calculate the average waiting times as well as the average service times for each of the following (Visa clearance counters, Luggage, Security check & Customs, Gate delay) as well as the time taken to reach each of these counters from one place to the other. This simulation has provided us with useful data to further improve the times and reduce the time taken for each of the previously mentioned functions and have an efficient airport.

References

[1] D. Kendall, "Stochastic Processes Occurring in the Theory of Queues and their Analysis by the Method of the Imbedded Markov Chain", *The Annals of Mathematical Statistics*, vol. 24, no. 3, pp. 338-354, 1953. Available: 10.1214/aoms/1177728975.

Appendix

main.m

```
clear;
clc;

configDEP = [20, 0.2, 2.1, 3, 2, 5, 15, 2, ...
     0, 5, 1, 1, 1, 1];
configARR = [0.2, 0.2, 1/12, 1/12, 3, 8, 1, ...
     5, 10, 5, 30, 3, 8, 2, 5, 10, 0.01, 4, ...
     2, 4];

simulationReport = ...
     GENERAL.simulateAirport(365, ["RUSSIAN ...
     Airlines", "French Airelines"], ...
     configDEP, configARR);
```

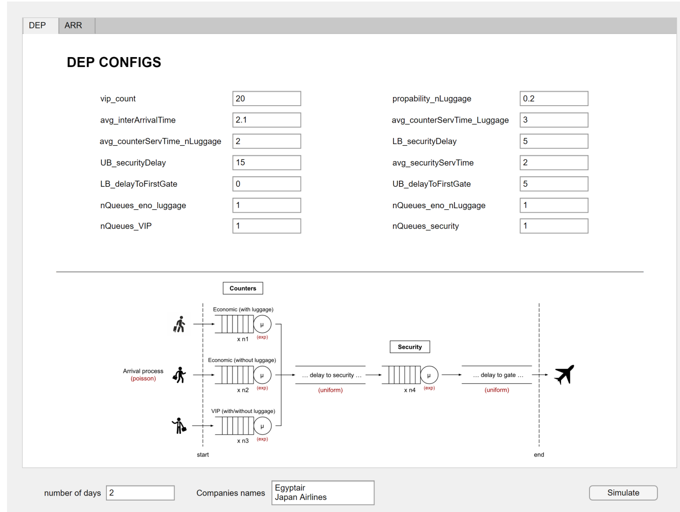


Fig. 12: User Interface 1

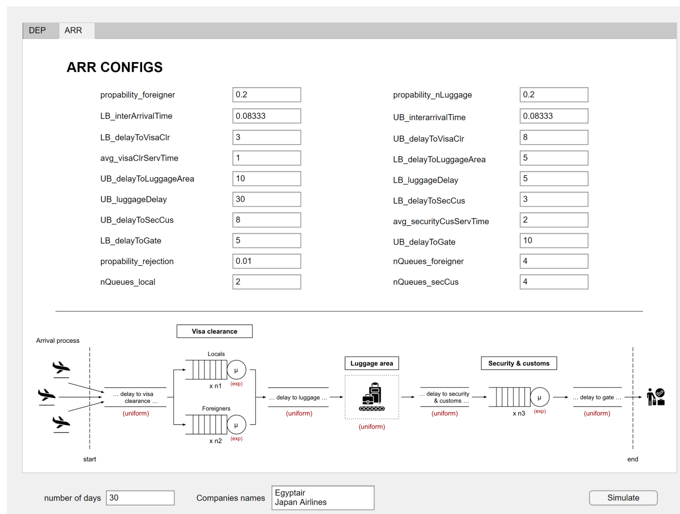


Fig. 13: User Interface 2

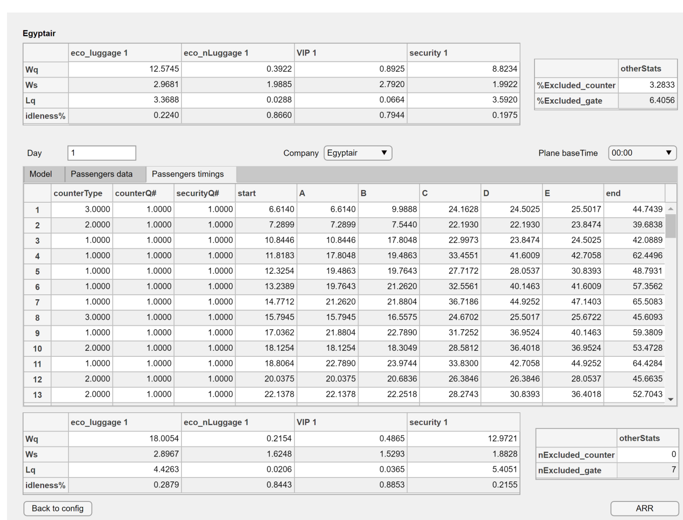


Fig. 14: User Interface 3